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Impact of damping on decay time of free oscillations in metal structures

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Abstract. The problem of increase of durability of the bearing thin walled metal structures of hoisting - and - transport machines maybe solved by means of structural damping which allows to increase the logarithmic decrement of the damped oscillations. In the work there are given the results of modelling and experimental check of the advantages of usage low-modulus foam materials as fillers at a structural damping of thin walled elements of metal structures. With the help of computational package SolidWorks there was conducted a numerical study to define amplitude-frequency characteristic of laboratory machine and then there were run the tests of model structure with building vibrorecord. As a result if research there was revealed a significant increase of the logarithmic decrement and reduction of the time of decay of natural oscillation of the foamed structure. Consequently, there are shown the advantages of the further researches to use energy-intensive foam materials to dampen the elements of the structures of handling machinery.

1. Introduction

In the building industry and aircraft manufacturing sandwich plate and shells have been used for a long time and successfully, which have a layer of low-modulus energy-intensive material. Extensional dampening is considered to be not effective thus it is not used in structures of handling machinery. It is appropriate to anticipate cost effective natural testing of real structures with numerical studies with beams of a simple structure.

Filling of the working in bending thin walled structures of a box section with a light low modulus foam material effectively damps free oscillations. Such a conclusion is rendered by numerous and natural tests which revealed a significant increase of the decrement of the beam free oscillations [1,2]. As a result of decrease of the amplitude and the number of significant oscillations the growth of longevity is forecasted [1, 3], improvement of ergonomic specifications of the structure. In the article there is analyzed one more aspect of structural dampening which concerns the increase of workforce productivity and human factor related to decrease of oscillation decay time.

The problem of free oscillation decay time is characteristic for the machines of cyclic operation with a frequent repetition of operational transient behavior. Oscillations of the structures of the significant mass are run with a large interval and time of dampening. For instance, the time of dampening of travelling crane maybe up to ten-fifteen seconds [4], that seriously increases the longevity of the operational cycle. The problem is especially sharply revealed in handling machinery with a fine



positioning of the freight: in the cranes with a rigid suspension of the freight, manipulators, hoists, etc. A long expectation of the freight oscillations has a negative psychological impact on machine's operator. Below are the results of numerous tests and laboratory tests with building vibrorecords of an empty and foamed outrigger beam which are partially present earlier in the works [1, 2]. As well as the results of calculation of the time of dampening oscillations of the longitudinal beam of the bridge crane.

2. Results of numerous any natural experiment with building vibrorecords of outrigger beam

On the basis of relation of the coefficient of dampening with cyclical frequency of free and dampening oscillations there is received an expression for logarithmic decrement of the foamed beam [1]:

$$\delta_2 = \frac{1}{\omega_2} \sqrt{(\delta_1 \omega_1)^2 + \omega_1^2 - \omega_2^2} . \quad (1)$$

where ω_1, ω_2 – eigen frequency of empty and foamed beam received from computational experiment in the environment SolidWorks Simulation, δ_1 – decrement of an empty beam which is taken from literature or natural experiment. There are recommendations by values of logarithmic decrement of oscillations of crane structures (table 1) [4]. In the absence of recommendations $\delta_1=0,05$ is taken.

Table 1. Values of logarithmic decrement of oscillations for different structures [4].

Box-type span of bridge cranes	0,05÷0,12
Bearing strictures of travelling bridge crane	0,10÷0,25
Bearing structures of transfer gantries	0,30÷0,40

Dampening time t_3 of free oscillations is calculated as a product of number of significant cycles N for interval of oscillations T :

$$t_3 = N \cdot T, \quad (2)$$

where $N = -\ln(0,1)/\delta$ – is a number of cycles to tenfold decrease of the amplitude of dampening oscillations, $T = 1/\omega$ – average period of oscillations.

For research there was chosen a beam from a rectangular tube which has a box-shaped section (figure 1) with a width b =mm, height h =mm and length l =mm. Base frequency of oscillation of the beam were defined for the walls with a width $s \in [0,2;1,5]$ mm. The material of real console St3sp, thus its analogue is used DIN 1.0116 (S235J2G3). Fixing method – rigid restraint from one of the sides. According to the found eigen frequencies ω at different wall thickens S and formulas (1) and (2) there built graphics of the time of dampening of the foamed beam (figure 2) at different decrements of empty beam δ_1 .

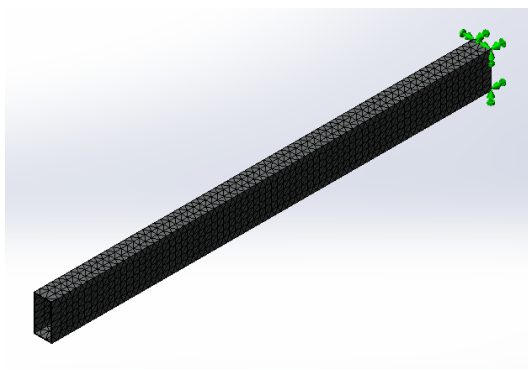


Figure 1. Finite-element model of the beam.

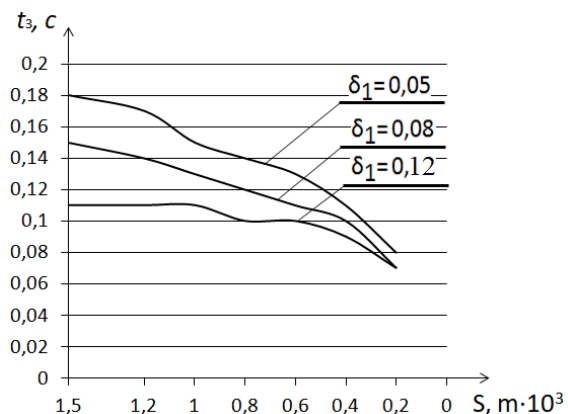


Figure 2. Estimated vibration damping time.

The calculated time of dampening of the oscillations decreases with decrease of the wall thickness of the beam section and growth of logarithmic decrement of the oscillations. This conclusion of the numerous experiment is qualitatively confirmed by the results of steel structure with a width 0,mm in laboratory conditions. During recording of the experiment there was used a high-speed recording camera in mobile phone Samsung S9, which allows to make shots with the frequency 960 Hz. As a filler assembly foam Kudo Window was used after setting during 24 hrs. The processed results of the experiments are given in table 2; logarithmic decrement of dampening, oscillations interval, eigen frequency, number of significant cycles and dampening time.

Table 2. The results of processing the experimental data.

Parameter	Empty beam	Foamed beam
Logarithmic decrement δ	0,08	0,14
Oscillations interval T , s	0,01042	0,01354
Frequency ω , Hz	96	73,85
Number of significant cycles N , psc.	29	16
Dampening time T_3 , s	0,3	0,22

The calculated time of oscillations of the foamed beam is decreased for 37% and the experimental one for 27%. The received difference is explained by differences in boundary conditions of the beam in the experiment and in its calculated scheme. However, the decrease of the time of free oscillations at filling the beam with foam material maybe considered to be significant. Consequently, further the results of calculation of the time of dampening free oscillations of longitudinal beam of the traveling crane with a carrying capacity 20 tons are given.

3. Results of numerous experiments to define the time of oscillations dampening of longitudinal beam

Longitudinal beam of box beam relates to wall thinned structures and is confirmed and exposed to flexural vibration in vertical and horizontal platitudes. That means the appropriate object for assesemnt the effect of foaming the real structure. The beam with an aperture 19,5 m designed by the method [5], has a section with a height 1,1m, width 0,6m with a thickness of the wall 9mm. Finite-element model of the longitudinal beam is given in figure 3.

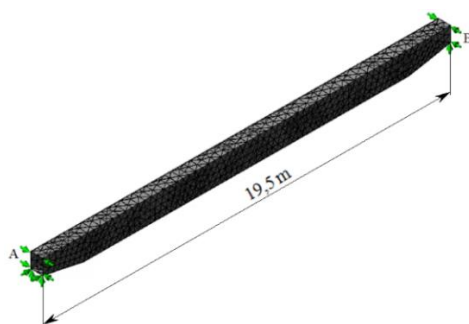


Figure 3. Finite-element model of the longitudinal beam.

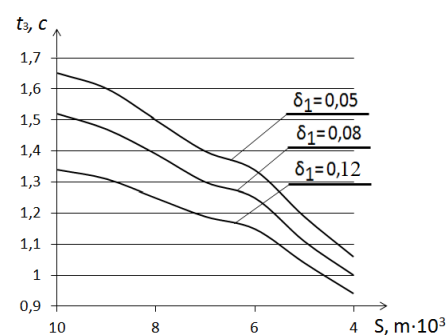


Figure 4. Change of the dampening time of longitudinal beam in dependence on the thickness $s \in [4;10]$ mm and beginning decrement δ_1 .

Calculations which are analogous to those that were conducted for the model beam are made for the longitudinal beam of the crane. In figure 4 there given the schedules of the change of dampening of vertical oscillations of the foamed longitudinal beam within the range of the change of the decrement of empty beam (table 1). For instance, at $\delta_1 = 0,08$ and $s=9\text{mm}$ value $\delta_2=0,178$, dampening time of empty beam 3,28s, and foamed beam 1,47s. Graphs in Drawing 2B allow to give interval assessment of calculated values of the dampening time of oscillations of the foamed beam in the selected interval of the change of the thickness of the section wall. The problem to increase the longevity and speed of hoisting-and-transport machines is solved by means of decrease the dynamics and increase of the durability. To decrease the dynamics there are used frequency electric motors with a smooth change of accelerations in start-breaking conditions [6,7], different ways to quench oscillations [8], as well as “active dampening” is used [9]. The considered ways are connected with the usage of complex electric and hydromechanics systems.

Currently foam metallic articles are used for dampening metallic structures in automobile and aerospace fields [10], as well as in machine-tool industry [11]. These foam metals have a relatively small density (about 500 kg/m^3) and improve the dampening characteristics of foam filled tube, meanwhile the other dynamic characteristics are practically constant [11]. The most popular ways to receive foam metals – casting or metal powder industry [12], that increases the cost of the structure and complicates manufacturability. The problem of the choice of a light and energy intensive material for structure dampening of longitudinal and console structures of metallic structures is still open. Application of a simple mounting foam as a filler gives a significant reduction of the dampening time of free oscillations of the thin walled metallic structure which works in bending.

4. Conclusion

Search of a reliable and cost-effective methods of structure dampening which may compete by its efficiency with the known ways of dampening oscillations of metallic constructions is actual for many fields. The given results of numerous and natural experiments give the basis for continuation of the researches to apply foam material as a filler of thin walled elements of the structures which work in bending. The further works are connected with the choice and technology of insertion of the filler into the structure, parametrical analyses of the efficiency of partial filling of free volume, research of dampening the other kinds of oscillations.

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